

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Results of an Interlaboratory Fatigue Test Program Conducted on Alloy 800H at Room and Elevated Temperatures

(NASA-CR-174940) RESULTS OF AN
INTERLABORATORY FATIGUE TEST PROGRAM
CONDUCTED ON ALLOY 800H AT ROOM AND ELEVATED
TEMPERATURES Final Report (Akron Univ.,
Ohio.) 38 D HC A03/MF A01

NE5-32340

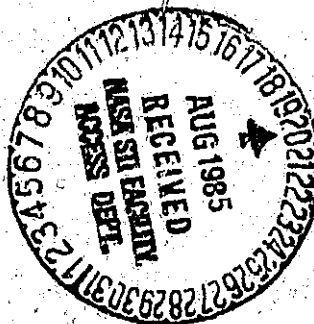
Unclas
CSCI 20K G3/39 21947

J.R. Ellis

*The University of Akron
Akron, Ohio*

July 1985

Prepared for
Lewis Research Center
Under Contract NAG 3-379



NASA

National Aeronautics and
Space Administration

FOREWORD

The author wishes to thank W. F. Burke and D. R. Diercks at Argonne National Laboratory; D. A. Utah and C. E. Jaske at Battelle, Columbus; R. H. Stentz and J. B. Conway at Mar-Test; and G. R. Halford and A. J. Nachtigall at NASA-Lewis.

Thanks are also due to C. J. Neff Jr. for laboratory assistance and to D. I. Roberts and J. F. Watson for support and encouragement.

RESULTS OF AN INTERLABORATORY FATIGUE TEST PROGRAM
CONDUCTED ON ALLOY 800H AT ROOM
AND ELEVATED TEMPERATURES

J.R. Ellis
The University of Akron
Department of Civil Engineering
Akron, Ohio

SUMMARY

A number of difficulties were encountered in early low-cycle fatigue tests conducted at General Atomic Company (GAC). The experimental approach adopted for this work involved the use of electro-hydraulic test systems, hour-glass geometry specimens, diametral extensometers, and axial strain computers. Attempts to identify possible problems areas with this approach were complicated by the lack of reliable data for the particular heat of Alloy 800H under investigation. The method adopted to resolve this difficulty was to generate definitive test data in an Interlaboratory Fatigue Test Program. This paper describes the results of this program and the subsequent evaluation work.

The laboratories participating in the program were Argonne National Laboratory, Battelle Columbus, Mar-Test, and NASA-Lewis. Fatigue tests were conducted on both solid and tubular specimens at temperatures of 20, 593 and 760°C and strain ranges of 2.0, 1.0, and 0.5%. Considering first the results obtained using solid specimens, data generated at the higher strain ranges were in good agreement whereas data generated at the lower strain ranges were for the most part in poor agreement. The problem at the lower strain ranges was caused by improper test system control which resulted in distorted hysteresis loops and unreliable fatigue data. Cyclic lives determined using thin-walled tubular specimens were found to be a factor of 2 less than those for

solid specimens. Localized buckling in the tubular specimens was thought to be the cause of this discrepancy.

Analysis of the results showed that data determined at GAC were about average. It appeared, therefore, that no special problems existed with the system under evaluation. More importantly, it was concluded that use of hourglass geometry specimens, diametral extensometers, and axial strain computers, can, under certain circumstances, result in fatigue data which are seriously in error. As a result, this approach subsequently was abandoned at GAC in favor of parallel gage length specimens and axial extensometers.

INTRODUCTION

A number of testing techniques have been developed to investigate low-cycle fatigue behavior at elevated temperatures. One such technique, described in detail in Ref. (1), involves subjecting hourglass geometry specimens to push-pull loading on closed-loop, electro-hydraulic test systems. Specimen heating is accomplished using a radio frequency (RF) induction heater and transverse strain is measured using a diametral extensometer. A load cell is positioned in series with the specimen, the load signal being combined with the signal from the diametral extensometer to obtain an electrical analog of axial strain, Fig. (1). Tests are controlled using this analog value in conjunction with a signal of triangular wave-form obtained from a function generator. Use of this particular waveform allows both strain range and strain rate to be held at fixed values throughout the test. Fatigue life is defined as the number of cycles at which stress range has fallen by say 5 or 10 percent due to the growth of macroscopic cracks.

Early attempts to use this test method at General Atomic Company (GAC) produced a number of unexpected results. First, extreme difficulty was experienced in maintaining test system control during experiments conducted on Alloy 800 H. This problem appeared to result from discontinuous yielding of the material during the first few cycles of tests, Fig. (2). Further questions regarding the adequacy of the test equipment were raised when the results of successful experiments were compared to data obtained from references (2) and (3). Such comparisons showed that cyclic lives determined at GAC tended to fall short of existing data at the higher strain ranges, say above 1%, whereas the opposite was true at the lower strain ranges. This trend, illustrated in Fig. (3), was noted in all fatigue data determined in the range 20°C to 760°C.

Attempts to identify possible problem areas with the test equipment and procedures used at GAC were complicated by the lack of reliable low-cycle fatigue data for the particular heat of material under investigation. It appeared that the most straightforward method of resolving this difficulty was to generate definitive test data for the material of interest in an Inter-Laboratory Fatigue Test Program. Comparison of data generated in this manner could then be used to evaluate the GAC experiments. Adopting this approach, four laboratories engaged in high-temperature fatigue testing were contacted and agreed to participate in the program. These laboratories were Argonne National Laboratory, Battelle Columbus, Mar-Test, and NASA-Lewis.

TEST PLAN

The test conditions selected for the program along with predictions of cyclic life and time to failure are summarized in Table (1). As the time available for this work was limited at all laboratories, an attempt was made to minimize the total time required for testing. Thus, only single tests were planned at each test condition and the longest cyclic life was limited to about 4×10^4 cycles.

The three temperatures selected for the program were 20, 593 and 760°C. Tests were planned at room temperature so that base-line data would be available free from possible specimen heating and temperature measurement errors. The intermediate temperature, 593°C, was selected because most difficulty with test system stability had been experienced at this value. The highest temperature approximates the upper limit of use of Alloy 800H in nuclear reactor application and so represents a temperature of major engineering interest.

Three values of strain range, 2.0, 1.0, and 0.5%, were chosen with the aim of covering a wide range of cyclic life while at the same time, maintaining test durations within acceptable limits. The tests at 2% were of particu-

lar interest since the experience of several laboratories had shown that if specimen buckling is a problem, then its effects become readily apparent at this strain range. A single value of strain rate, $4 \times 10^{-3} \text{ sec}^{-1}$, was selected to facilitate comparison with earlier data.

The definition of fatigue life adopted for the program was the number of cycles corresponding to a five percent drop in tensile stress amplitude, N_5 . This particular value was preferred over smaller percentage drops as it allows failure to be identified with more certainty. Regarding use of tensile stress amplitude, prior testing had shown that it provided a more reliable measure of failure than corresponding drops in total stress range. This was because values of peak compressive stress tended to vary in an erratic manner once cracks were initiated.

EXPERIMENTAL DETAILS

As previously stated, the aim of the program was to generate definitive fatigue data for a particular heat of Alloy 800H and to use these data to evaluate the experimental approach used at GAC. It was clearly important to maintain internal consistency with regards to specimen fabrication techniques. Therefore, all specimens used in the program were manufactured from a single heat of Alloy 800H, Huntington Alloys heat number HH 5556 A, by a single machinist working to a single set of detailed instructions.

Unfortunately, it was not possible to adopt a single specimen design for the program. As indicated in Fig. (4), the same design was used at GAC, Battelle and Mar-Test. This design features an hourglass geometry with 50 mm radius, a 6.4 mm minimum diameter, and threaded ends for attachment purposes. A similar design was used at Argonne, as shown in Fig. (5). In this case, the hourglass radius was 38 mm and button-ends were used for attachment.

The specimen used at NASA-Lewis, Fig. (6), can be characterized as being tubular in form with an hourglass-geometry detail at its midsection. The radius of this detail is 50 mm and the minimum wall thickness at the midsection is 1.5 mm. The ends of the specimen are threaded on the outside diameter for attachment purposes.

One common feature of the specimens described above is that they incorporate some form of hourglass profile. This characteristic necessitated the use of diametral extensometers by all participating laboratories. Although the various extensometers differed in detail, they all operate on the same basic principle, Fig. (7). Ceramic probes or knife edges are used to sense changes in specimen diameter. These changes are transmitted via an elastic hinge to a linear variable differential transformer (LVDT) which provides an electrical analog of diametral strain in the form of a DC voltage. Calibration experiments are performed prior to testing to establish exact relationships between simulated changes in specimen diameter and LVDT voltage output. The extensometer used at GAC differed in one regard from the instruments used at the other laboratories in that provision was made for hydraulic or mechanical damping. This feature was incorporated to make the device less sensitive to external vibration and to discontinuous material behavior. The hydraulic damping system was used in the present experiments as exploratory tests had shown that it had no significant effect on cyclic response at the strain rate of interest.

One obvious disadvantage of using diametral extensometers is that the fatigue variable of primary interest, axial strain, is not measured directly. It follows that this variable cannot be controlled directly during tests. The approach adopted at NASA-Lewis to resolve this difficulty was to control di-

ametral strain range. The corresponding value of axial strain range is obtained manually using the expression,

$$\Delta \epsilon = \left(1 - \frac{\nu_e}{\nu_p} \right) \frac{\Delta \sigma}{E} + \frac{\Delta \epsilon_d}{\nu_p} \quad (1)$$

where $\Delta \epsilon$ = axial strain range
 $\Delta \epsilon_d$ = diametral strain range
 $\Delta \sigma$ = stress range
 E = Young's modulus
 ν_e = Poisson's ratio for elastic strains
 ν_p = Poisson's ratio for plastic strains

Inspection of the above expression shows that axial strain range will remain constant in tests controlled in this manner only if stress range remains constant. In other words, diametral strain control is equivalent to axial strain control when the material tested is cyclically neutral. For materials not falling into this category, adjustments have to be made to $\Delta \epsilon_d$ on a cycle-by-cycle basis to keep $\Delta \epsilon$ constant. Adjustments of this type are the primary function of the strain computer described previously (Fig. 1). The remaining laboratories in the program opted to use strain computers of this type and computed values of axial strain for control purposes.

One further difference in experimental approach relates to the method of specimen heating. The method adopted at NASA-Lewis involved use of silicon carbide heating elements positioned in the bore of the specimen (Ref. 4). The remaining laboratories used RF induction heaters with about 2-1/2 KW capacity. In all cases, temperature was controlled using closed-loop temperature con-

trollers in conjunction with Chromel-Alumel thermocouples spotwelded directly to the specimen's surface close to the midsection.

TEST RESULTS

During the planning stages of the program, guidelines, based on the procedures recommended in Ref. (5), were supplied to the laboratories regarding the approach to be adopted in acquiring data. It was suggested that plots of stress versus axial strain should be recorded at frequent intervals using X - Y plotters and that the variation of stress with cycles should be monitored continuously using strip chart recorders. Since reduction of data in this form requires a degree of interpretation, it was requested that all raw data be supplied to GAC so that a uniform approach could be adopted in its reduction. The intent was to produce data in three forms:

- (a) Stabilized hysteresis loops plotted as stress versus axial strain.
- (b) Cyclic stress-strain data plotted as stress amplitude versus strain amplitude.
- (c) Low-cycle fatigue data plotted as axial strain range versus cycles to failure.

Considering the first of these categories, the reduction process for data from Argonne, Battelle, GAC and Mar-Test simply involved identification of typical loops for material in a stabilized condition. For consistency, this condition was assumed to have been achieved at about half the cyclic life. The situation was less straightforward in the case of data from NASA-Lewis since it was recorded in the form of stress versus diametral strain. Here, it was necessary to convert the diametral strains to axial strains using equation (1) and to construct the hysteresis loops manually. The data determined using both these approaches are shown in Figs. (8), (9) and (10) for the three temperatures investigated. It should be noted that these loops represent average

behavior, the raw data from all laboratories exhibiting varying degrees of noise which is not shown for simplicity.

The stabilized hysteresis loops described above were used to obtain the cyclic stress-strain data shown in Fig. (11). The stress amplitudes and strain amplitudes plotted in this figure were obtained by simply halving the respective values of range. Also shown in Fig. (11) are curves representing average behavior for previous data generated at GAC.

Determination of low-cycle fatigue data in the form of axial strain range versus cycles-to-failure was again straightforward. As previously noted, failure in these experiments was defined as the number of cycles corresponding to a five percent drop in tensile stress amplitude. The data reduction process in this case involved identifying this value on the strip chart recordings of stress versus cycles. The corresponding value of axial strain range was obtained from a hysteresis loop judged typical for the experiment. Data determined in this manner for the three temperatures investigated are shown in Figs. (12), (13) and (14). Also shown are average fatigue life curves determined at GAC.

DISCUSSION

As indicated above, similar test equipment and procedures were used at Argonne, Battelle, GAC and Mar-Test. It followed that comparison of data obtained at these laboratories was a logical first step in evaluating the approach used at GAC.

Considering first the stabilized hysteresis loops, Fig. (8),(9) and (10), data generated using a strain range of 2% are in fairly good agreement for all temperatures. In contrast, hysteresis loops determined for lower strain ranges are not in such good agreement for temperatures of 20°C and 760°C and are in worse agreement for 593°C. At the latter temperature, the difference be-

tween the maximum and minimum stress range is about 10% while the corresponding difference in the plastic component of strain is almost a factor of two.

As might be expected, similar trends carry over to the cyclic stress-strain data and the low-cycle fatigue data. It can be seen in Figs. (12), (13) and (14), for example, that cyclic lives determined using a strain range of 2% are in excellent agreement for all three temperatures. Cyclic lives determined for lower strain ranges exhibit significant scatter at 20°C and 760°C, the longest lives exceeding the shortest by a factor of about five. This variability is even more pronounced at 593°C, one laboratory producing a cyclic life of about 30,000 cycles and two producing runouts.

Regarding possible problems with the approach adopted at GAC, these comparisons showed that the data generated at this laboratory were about average. It appeared, therefore, that no special problems existed with the test system under evaluation. More importantly, however, it was concluded that the use of hourglass geometry specimens, diametral extensometers, and associated strain computers, can under certain circumstances, result in fatigue data which differ greatly.

The trends noted above reflect to a large extent the ease or difficulty of running tests on Alloy 800H at the specified test conditions. This material exhibits discontinuous yielding over a range of thermomechanical conditions, the effect being most pronounced in this program at 593°C. As a result of this behavior, difficulties were experienced by all laboratories in maintaining test system control. This problem largely results from using computed values of axial strain for control purposes rather than measured values. As indicated in Fig. (1), this approach makes use of both load measurements and diametral strain measurements. This leads to stability problems when material response is nonlinear and time-dependent.

One method of minimizing this difficulty is to include stability circuits in the control system (Ref. 1). A second is to incorporate some form of mechanical damping on the diametral extensometer. Also, tests can be run under reduced hydraulic pressure and reduced control system gain. Although these measures may prove effective in maintaining servo valve stability, their use can result in distorted hysteresis loops and unreliable fatigue data, as will be discussed in more detail later in the paper.

Attention is directed next to the results of experiments conducted at NASA-Lewis. One feature of the NASA data is that cyclic lives fall short of average behavior by a factor of about 2, Figs. (12), (13) and (14). The reason for this difference, use of tubular specimens as opposed to solid specimens, is known with certainty as a result of more recent tests conducted on a high strength, low alloy steel. These tests, performed at NASA-Lewis in support of an ASTM Round-Robin Test Program, investigated the effect of specimen geometry on low-cycle fatigue behavior at room temperature. One series of tests was conducted on solid specimens of the type shown in Fig. (5) while a second was conducted on tubular specimens with the design shown in Fig. (6). The results of these experiments are shown in Fig. (15). Here, it can be seen that cyclic lives obtained using tubular specimens were less than those obtained using solid specimens by a factor of about 2. Several factors may have contributed toward these lower cyclic lives including:

1. Problems with the surface finish on the specimens bore.
2. A larger surface to volume ratio with the tubular specimens.
3. Localized buckling influencing failure.

Post-test examination of the tubular specimens used in the ASTM program indicated that the surface finish on the bore was less than ideal and was a factor

in reducing cyclic life. However, the fact that the differences increased as strain range was increased suggests that other factors were also involved. One possibility is that localized buckling in the tubular specimens played a role in reducing cyclic life.

Returning to the problem of distorted hysteresis loops and unreliable fatigue data, some insight as to the cause of this difficulty was obtained in a series of exploratory tests conducted at GAC. The first of these experiments was aimed at determining the effect of running fatigue tests under reduced hydraulic pressure and reduced control system gain.* All other control settings were kept constant including the span setting which controls the nominal value of strain range. The experiments were performed at 20°C on Alloy 800H in a fully cyclically hardened condition. Two strain ranges were investigated, 2.0% and 0.5%, these values representing the maximum and minimum strain ranges used in the Interlaboratory Fatigue Test Program. A single value of strain rate was used, $4 \times 10^{-3} \text{ sec}^{-1}$, and no form of damping was used in generating the results discussed here.

The stress-strain hysteresis loops determined for 0.5% strain range are shown in Fig. (16). It can be seen that for a hydraulic pressure of 3.45 MPa, the measured strain range fell short of the target value by about 15%. This situation was corrected for the most part when the hydraulic pressure was increased to 6.90 MPa. Varying control system gain was found to have little effect on cyclic response when the hydraulic pressure was 6.90 MPa or above.

* The values used at GAC in the Interlaboratory Fatigue Test Program were 13.8 MPa and 3.0. Prior testing had shown that this combination represented the best compromise for the material and test conditions selected for the program.

Similar trends were noted in the data generated for a strain range of 2% for identical combinations of hydraulic pressure and control system gain. In this case, however, the effect of changing these variables was less pronounced. More specifically, the measured strain range fell within 3% of the target value for all the conditions investigated. One factor here is that the cycle time for the two sets of experiments differed significantly. In experiments investigating a 0.5% strain range, the time required for individual cycles was 2.4 seconds. This value was 10.0 seconds in the case of the higher strain range. Another difference was that the rate of strain hardening was relatively low for the major part of the hysteresis loop for 2% strain range. Both of these factors caused the cyclic response of the material to be less sensitive to test system settings at the higher strain range. This raises the possibility that the scatter noted in Figs. (9) and (13) might have been reduced had the experiments been conducted at a lower value of strain rate, say 0.001 sec^{-1} .

A second series of exploratory tests performed at GAC investigated the effect of mechanical damping on cyclic response. Again, the experiments were conducted at 20°C on Alloy 800H in a fully cyclically hardened condition. The type of damping used in these experiments was the spring type shown in Fig. (7). Using this method, the amount of damping was varied by simply rotating the adjustment screw known amounts. The results obtained for a 1% strain range are shown in Fig. (17). Medium damping corresponded to 1/2 a turn of the adjustment screw from the "just touching" position and heavy damping corresponded to 3/4 of a turn. It can be seen in this figure that both levels of damping caused significant distortion of the hysteresis loops. The width of the hysteresis loop for heavy damping was about 1.4 times that for no damping. This distortion results from the signal from the load cell becoming

progressively more out of phase with the signal from the diametral extensometer as damping is increased. Thus, although the target value of strain range apparently is achieved successfully, the two quantities used to derive this value are not necessarily reflecting true material response. A similar situation can be produced electronically by varying the degrees of filtering applied to the load signal and the strain signal. This problem with phasing is viewed as an important shortcoming of the test method under consideration and is thought to be a major factor contributing to the data scatter noted in Figs. (9) and (13).

CONCLUSIONS

The following conclusions were drawn from this Interlaboratory Fatigue Test Program conducted on Alloy 800H.

1. The material investigated exhibits discontinuous yielding over a range of thermomechanical conditions, the effect being most pronounced in this study at 593°C.
2. The test method under evaluation was found to be highly susceptible to stability problems. Measures taken to maintain servovalve stability led to phasing problems which in turn led to unreliable test data.
3. Cyclic response was found to be influenced by experimental variables such as test system gain and hydraulic pressure. This raises questions regarding the practice of using hourglass geometry specimens and diametral strain measurements for generating cyclic stress-strain data.
4. Low-cycle fatigue data determined for a strain range of 2% were in good agreement whereas data generated at the lower strain ranges were in poor agreement. This suggests that use of the subject test method should be limited to the higher strain ranges only.
5. Cyclic lives determined in fatigue tests conducted on thin-walled tubular specimens were about a factor of 2 less those for solid specimens. Localized buckling in the tubular specimens was thought to cause this discrepancy at high strain ranges. At lower strain ranges, bore surface finish is responsible.

6. The data generated at GAC were about average indicating that there were no special problems at this laboratory. However, to avoid the possibility of generating questionable test data, the approach evaluated in this program subsequently was abandoned in favor of parallel gage length specimens and axial extensometers.

REFERENCES

1. Slot, T., Stentz, R. H., and Berling, J. T., "Controlled-Strain Test Procedures," Manual on Low-Cycle Fatigue Testing, ASTM STP 465, American Society for Testing and Materials, 1969, pp. 100-128.
2. Conway, J. B., "Short Term Tensile and Low-Cycle Fatigue Studies of Incoloy 800," General Electric Report, GEMP-732, December, 1969.
3. Jaske, C. E., Mindlin, H. and Perrin, J. S., "Low-Cycle Fatigue and Creep-Fatigue of Incoly 800," Battelle Memorial Institute Report, BMI - 1921, February 1972.
4. Hirschberg, M. H., "A Low Cycle Fatigue Testing Facility," Manual on Low Cycle Fatigue Testing, ASTM STP 465, American Society for Testing and Materials, 1969, pp. 67-86.
5. "ASTM Standard E606 - Standard Recommended Practice for Constant-Amplitude Low-Cycle Fatigue Testing," Vol. 03.01, Metals-Mechanical Testing; Elevated and Low-Temperature Tests, 1983, pp 652-666.

TABLE 1. - Test Conditions for the Cooperative Fatigue Test Program

Type of loading	Temperature, °C	Young's modulus, MPa	Strain rate, sec ⁻¹	Strain range, percent	Predicted cycles to failure	Predicted time to failure, hr
Continuous cycle	20	214x10 ⁶	4x10 ⁻³	2.0	1600	5
				1.0	8000	11
	593	159x10 ⁶	4x10 ⁻³	2.0	1000	3
				0.5	37 000	26
	760	145x10 ⁶	4x10 ⁻³	2.0	320	1
				0.5	4000	3

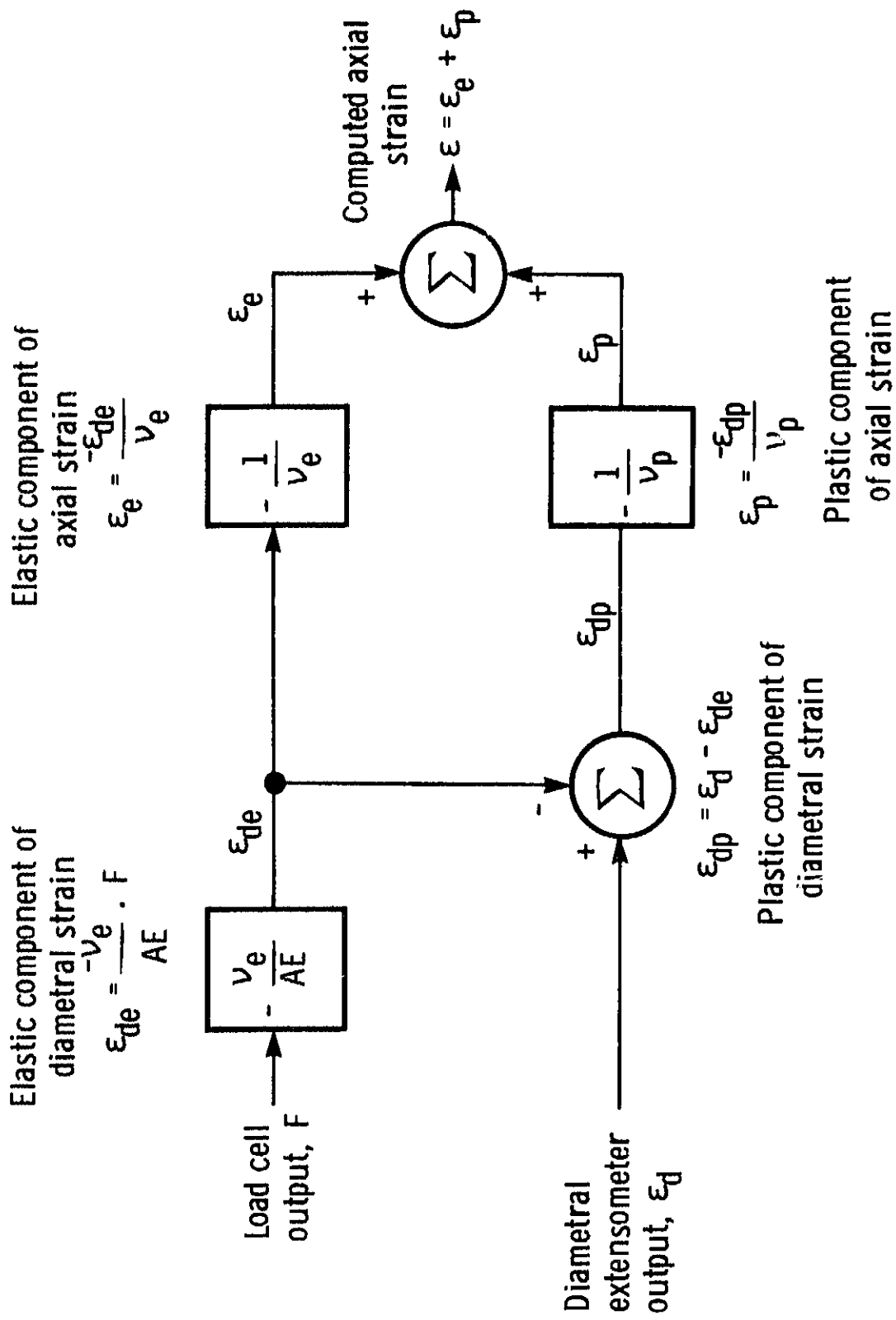


Figure 1. - Method of computing axial strain ϵ from measurements of load F and diametral strain ϵ_d .

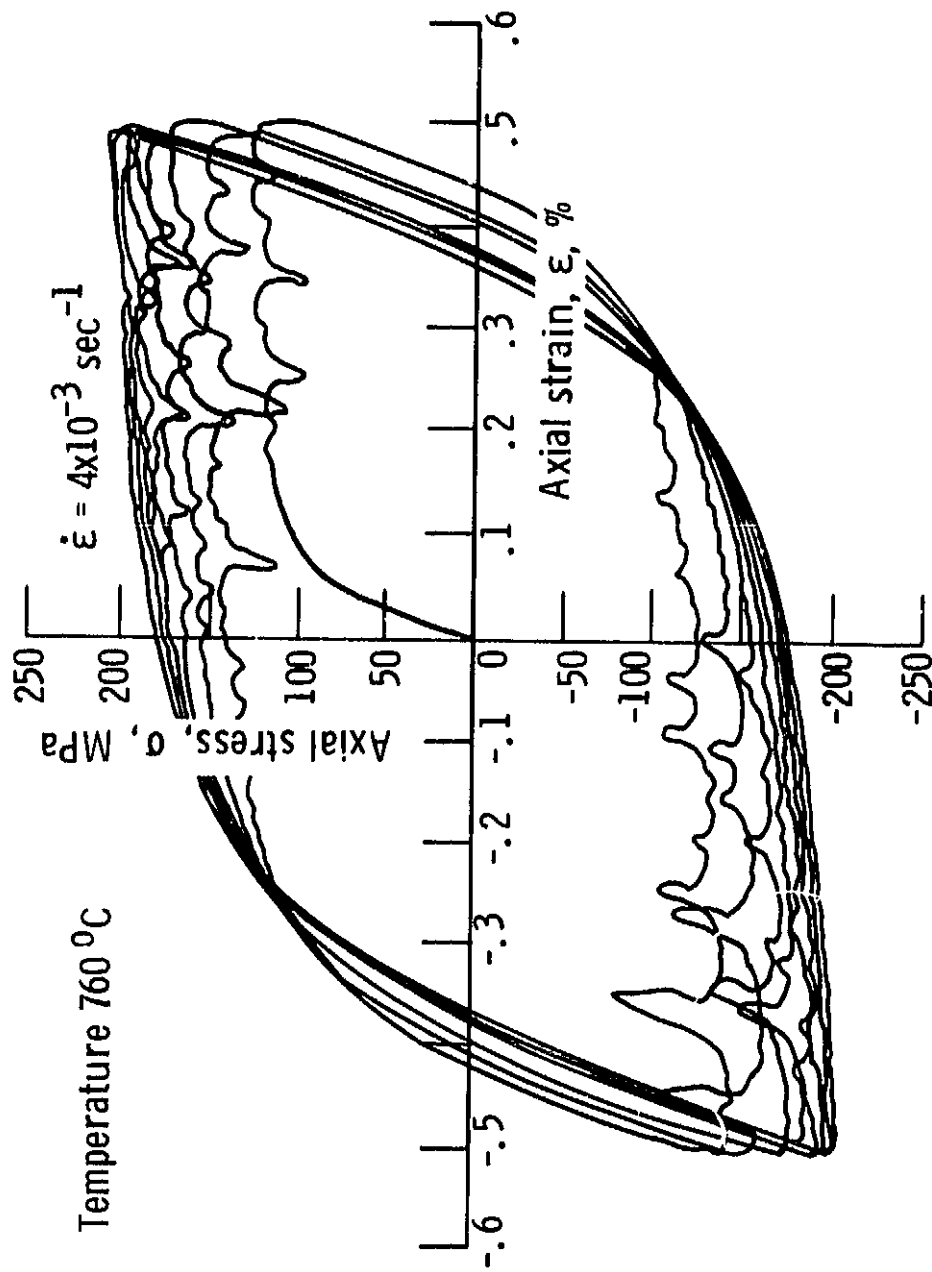


Figure 2. - Discontinuous yielding at the start of a low-cycle fatigue test on Alloy 800H.

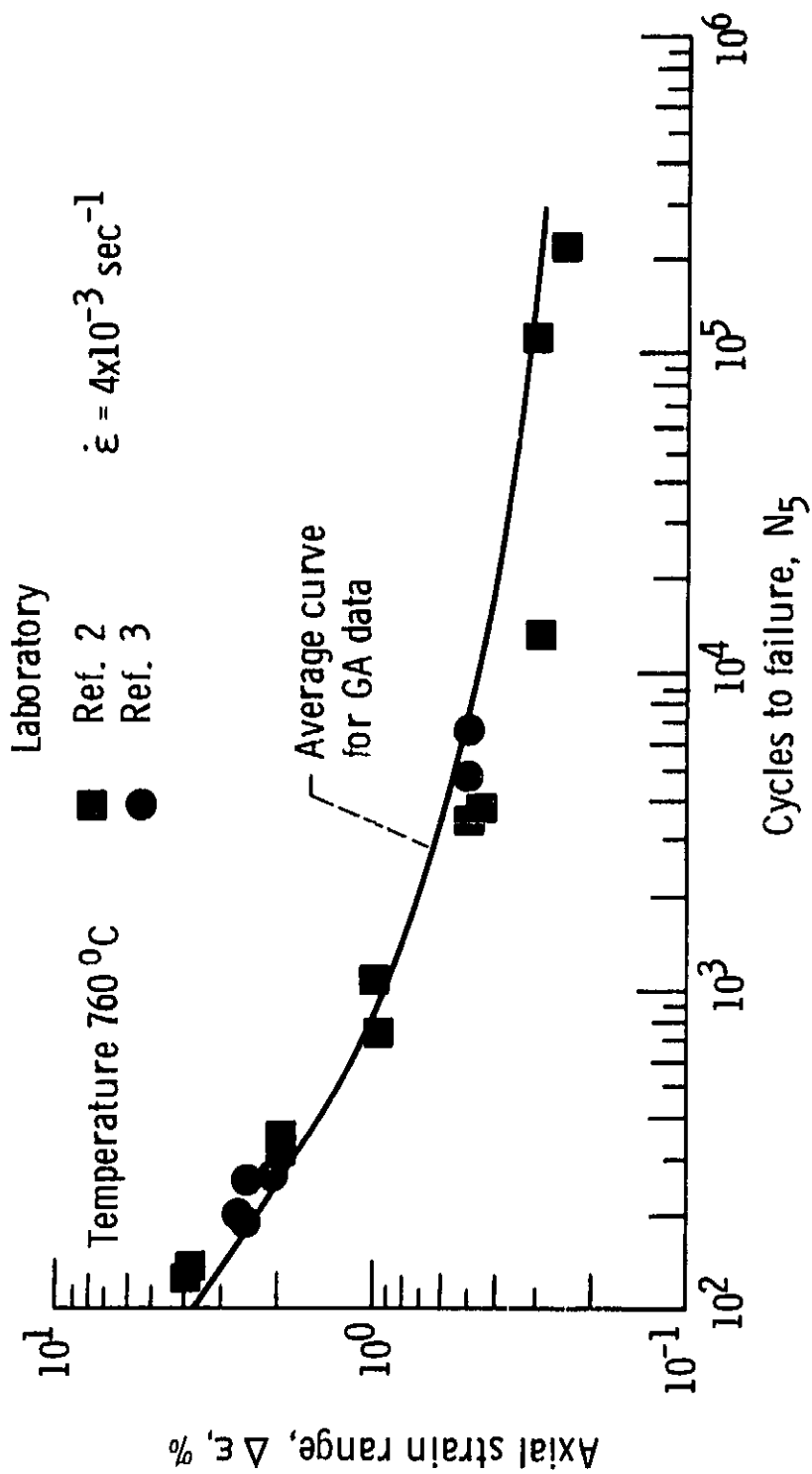


Figure 3. - Comparison of low-cycle fatigue data for Alloy 800H determined at three laboratories.

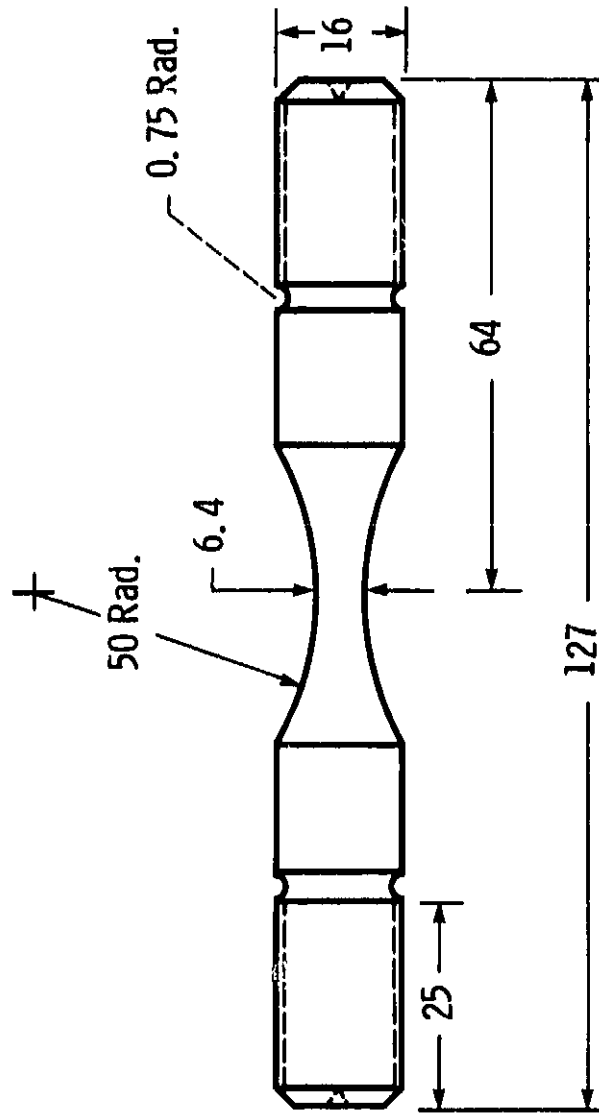
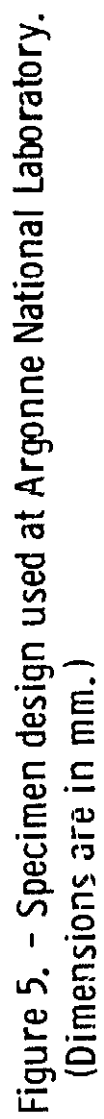


Figure 4. - Specimen design used at General Atomic, Battelle, and Mar-Test. (Dimensions are in mm.)



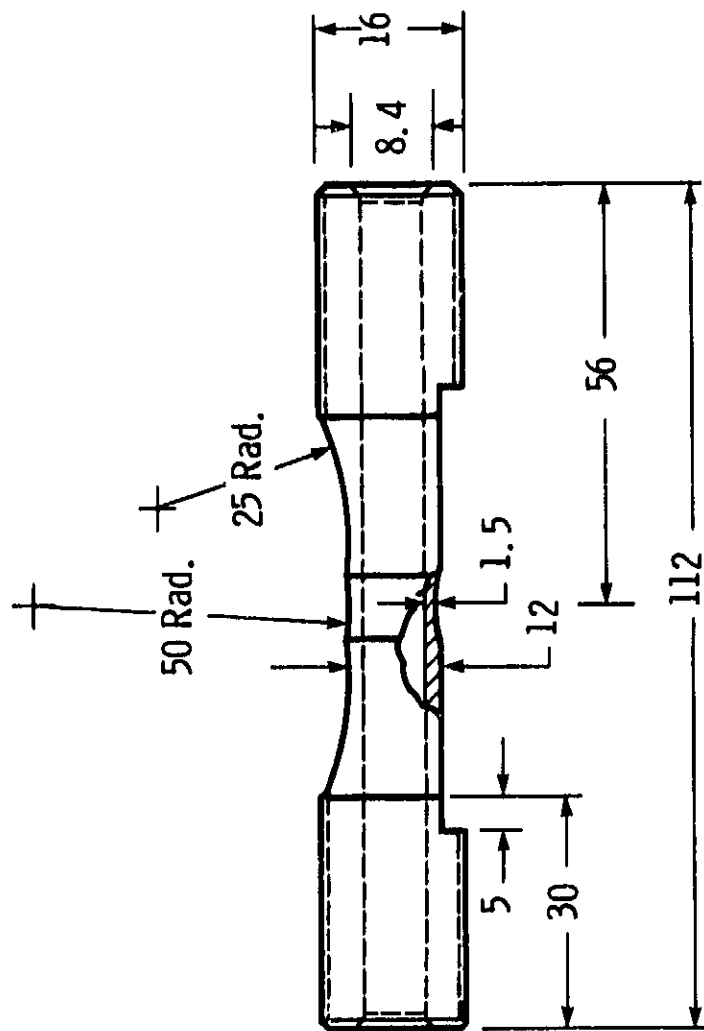


Figure 6. - Tubular specimen design used at NASA-Lewis.
(Dimensions in mm.)

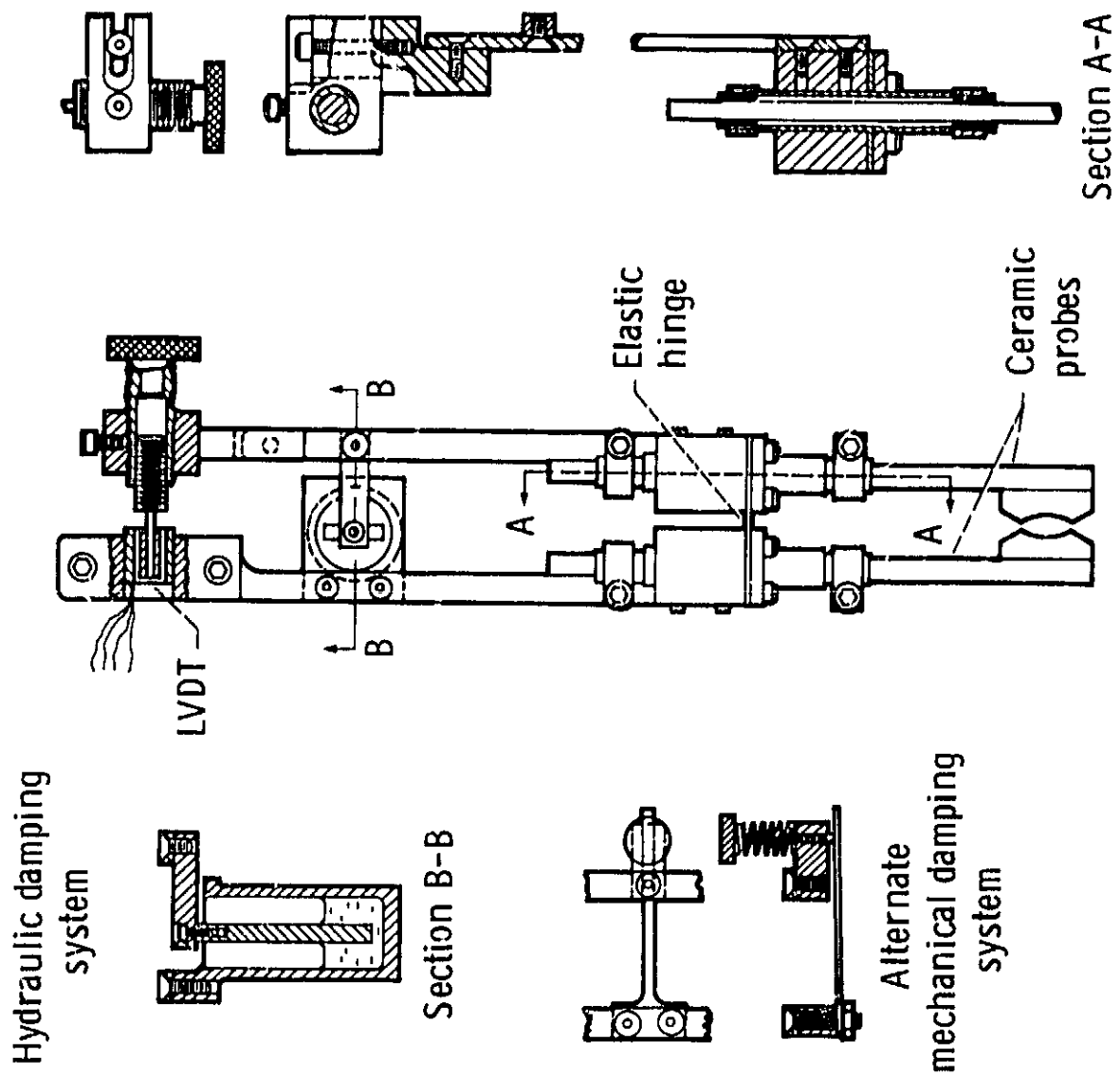


Figure 7. - Diametral extensometer with provision for hydraulic or mechanical damping.

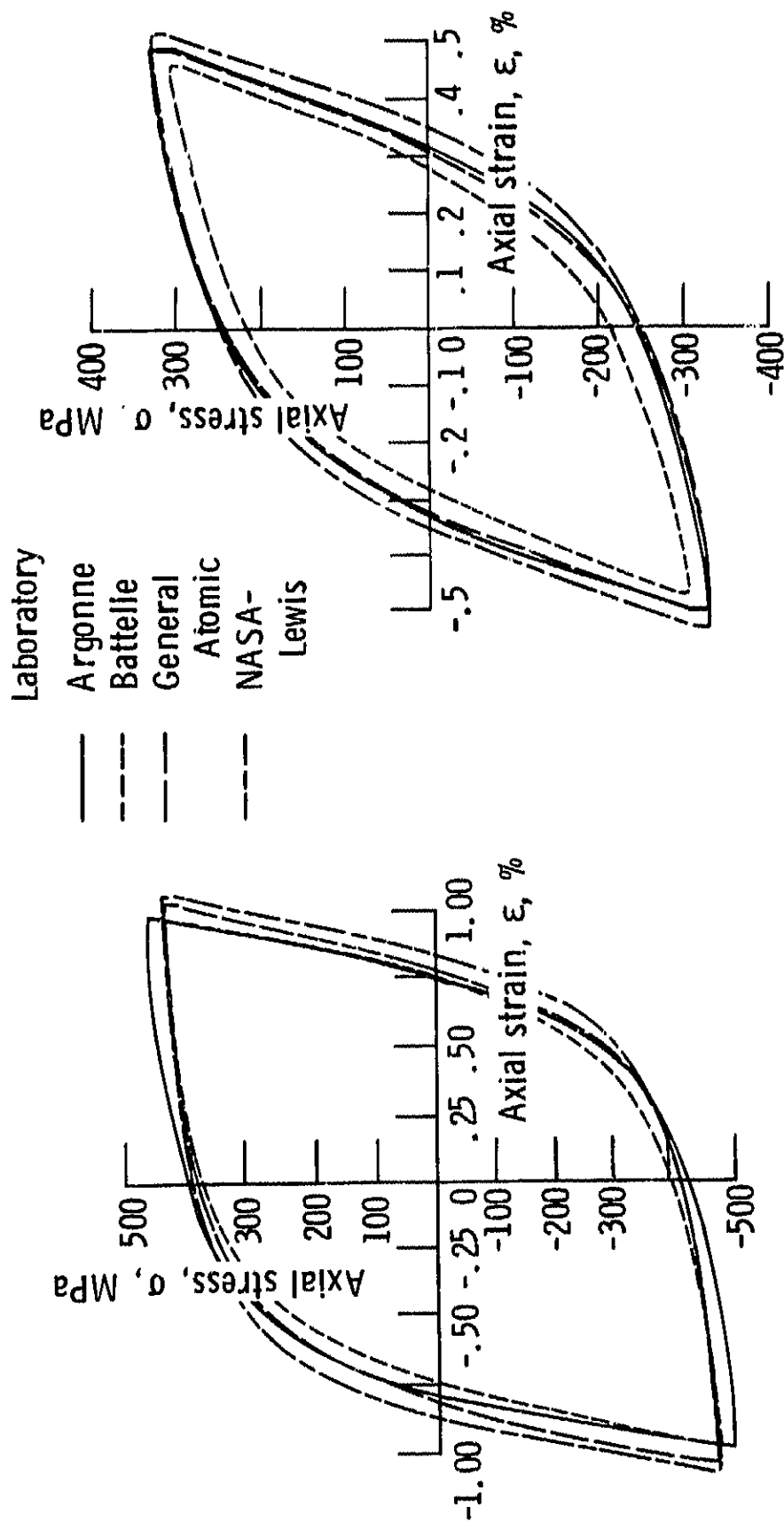
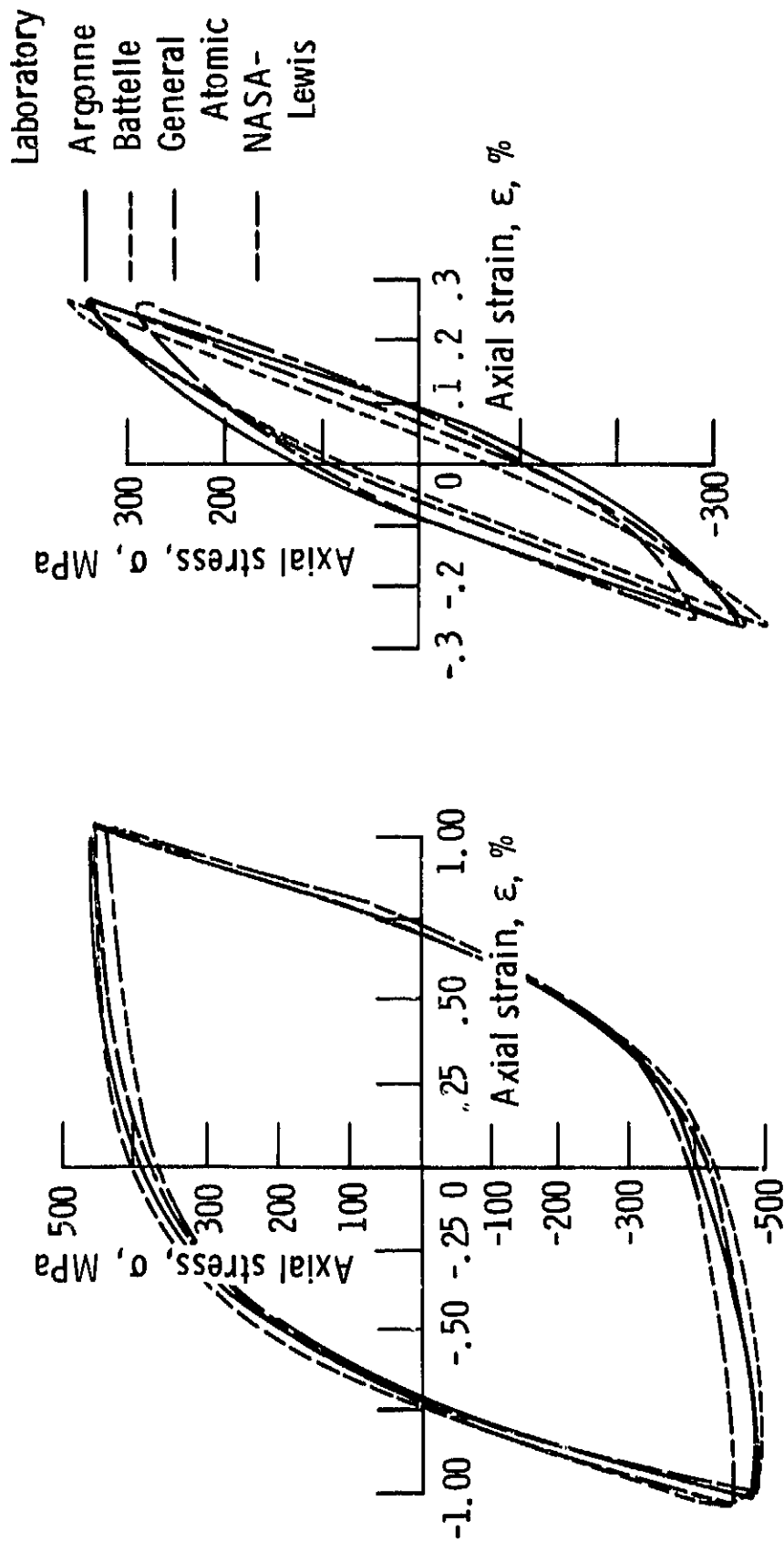


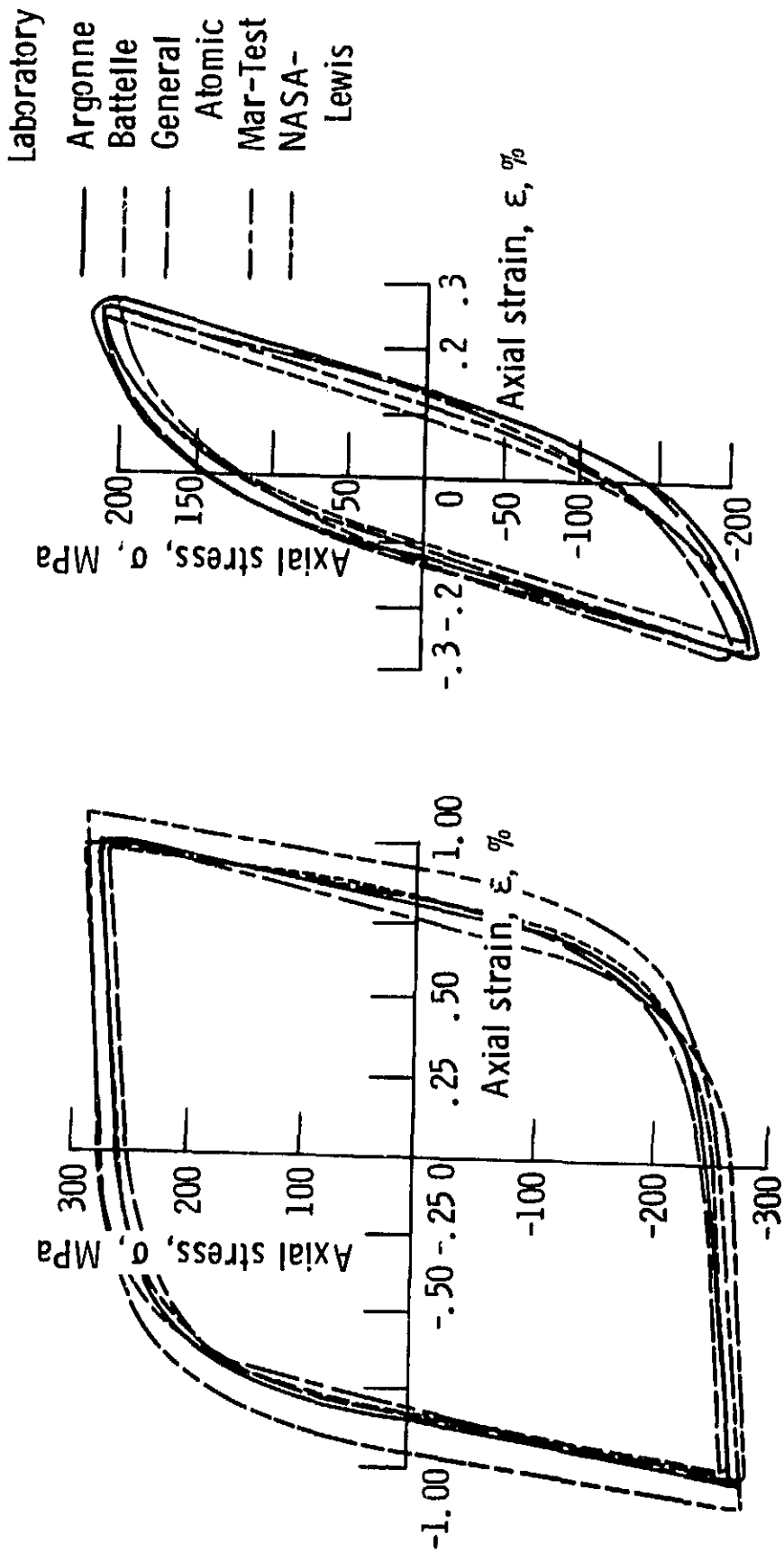
Figure 8. - Stress-strain hysteresis loops determined at 20 °C.



(a) 2% strain range.

(b) 0.5% strain range.

Figure 9. - Stress-strain hysteresis loops determined at 593°C.



(a) 2% strain range.

(b) 0.5% strain range.

Figure 10. - Stress-strain hysteresis loops determined at 760 °C.

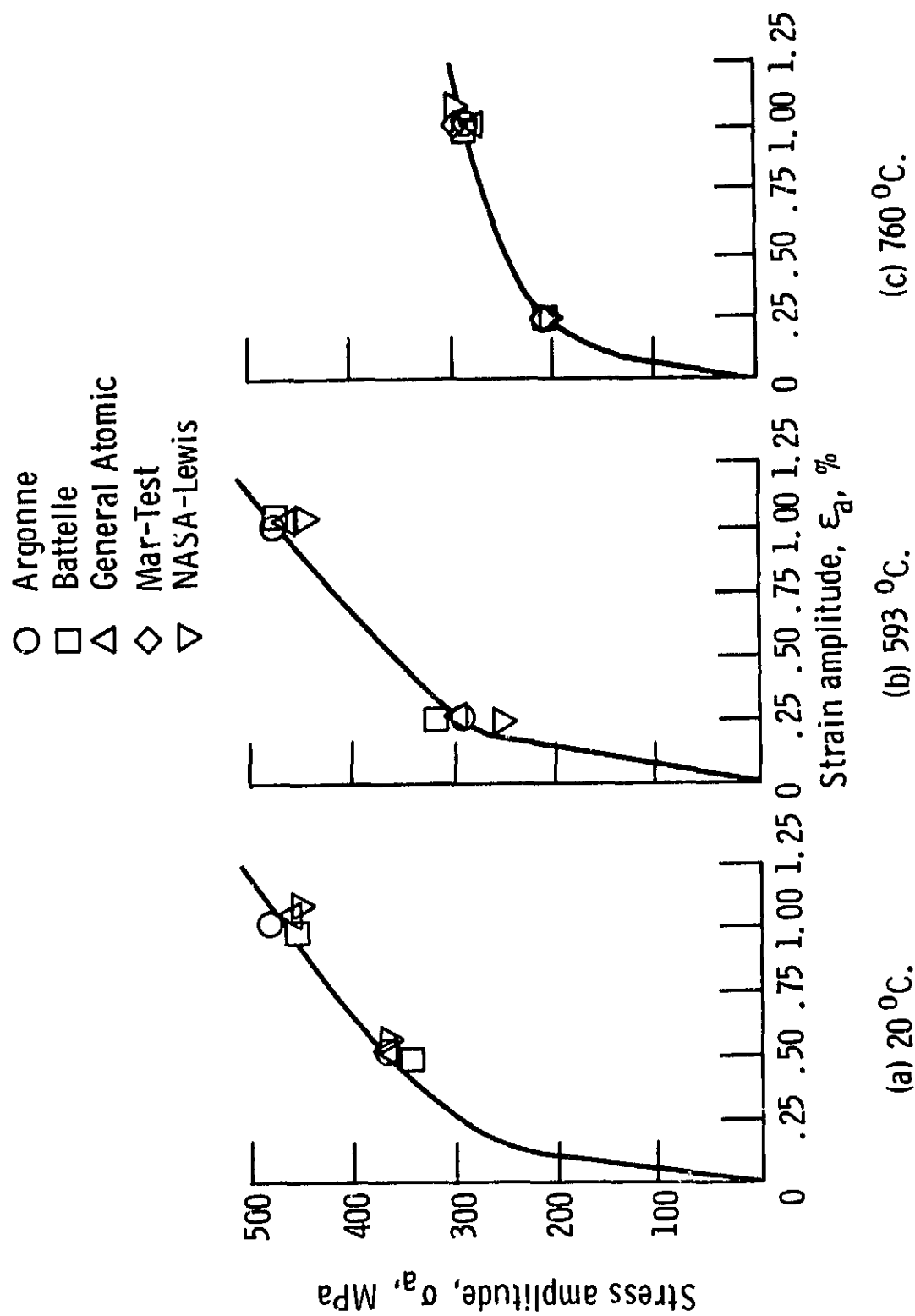


Figure 11. - Cyclic stress-strain data: stress amplitude σ_a versus strain amplitude ϵ_a .

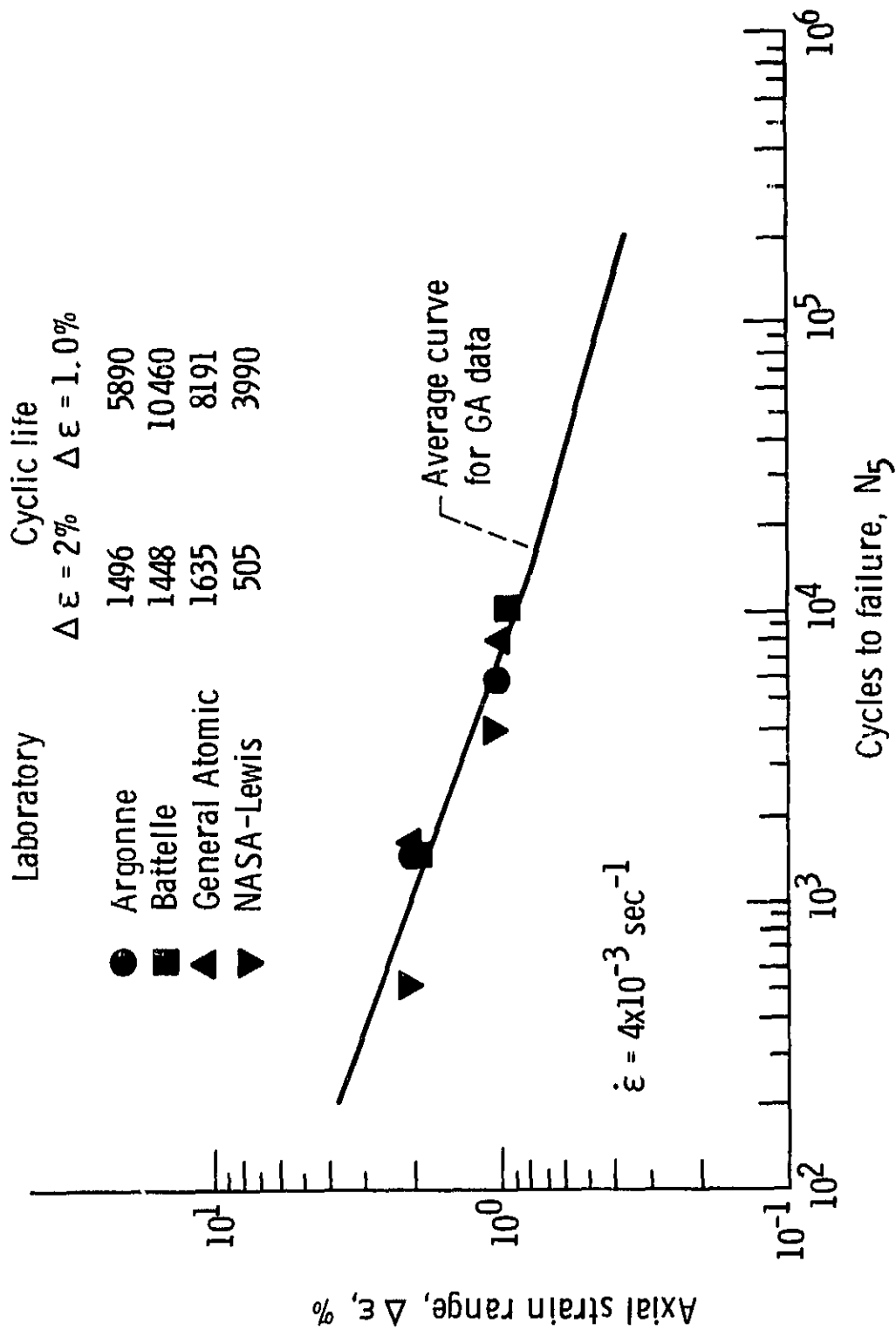


Figure 12. - Low-cycle fatigue data for Alloy 800H determined at 20 °C.

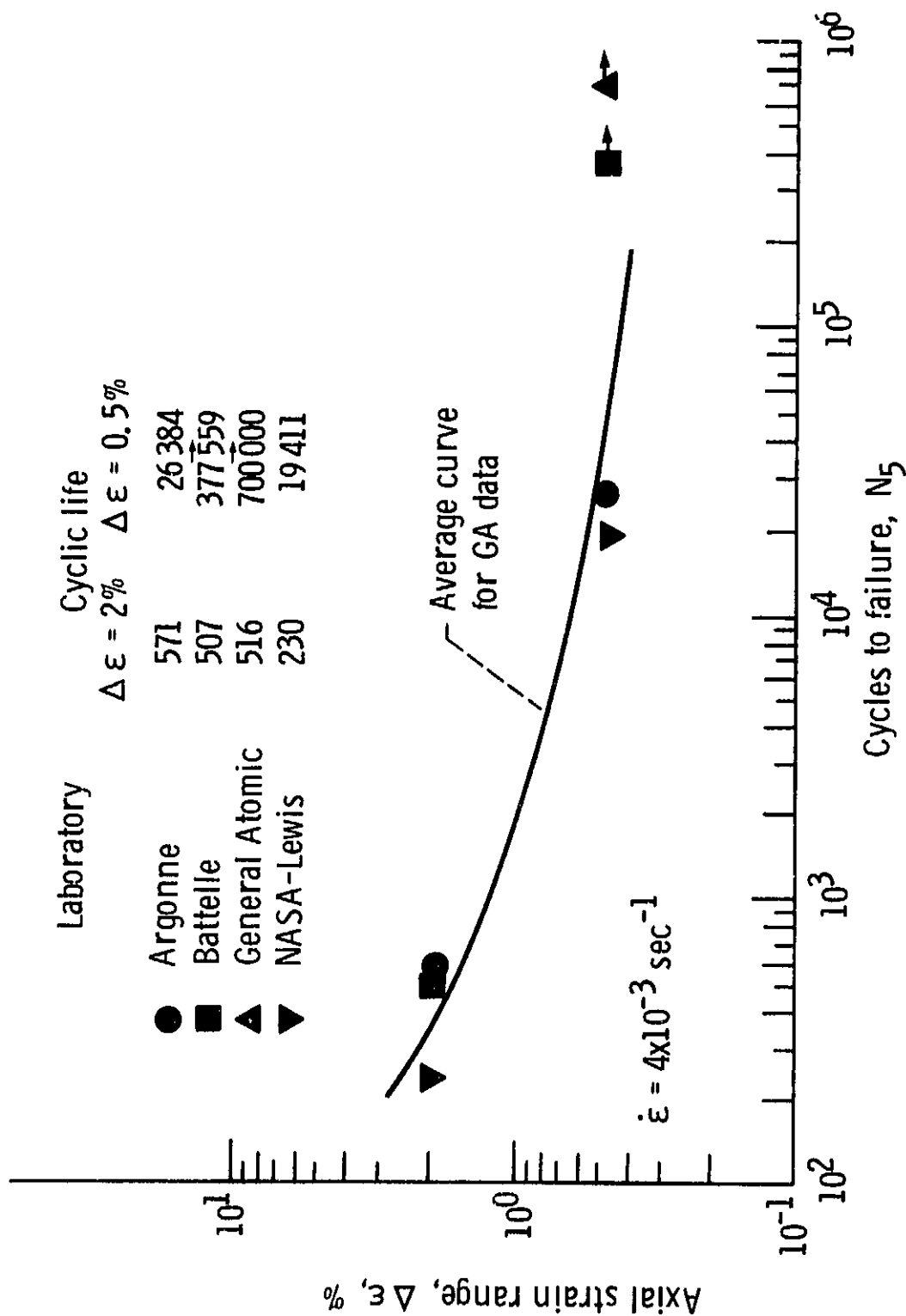


Figure I3. - Low-cycle fatigue data for Alloy 800H determined at 593 °C.

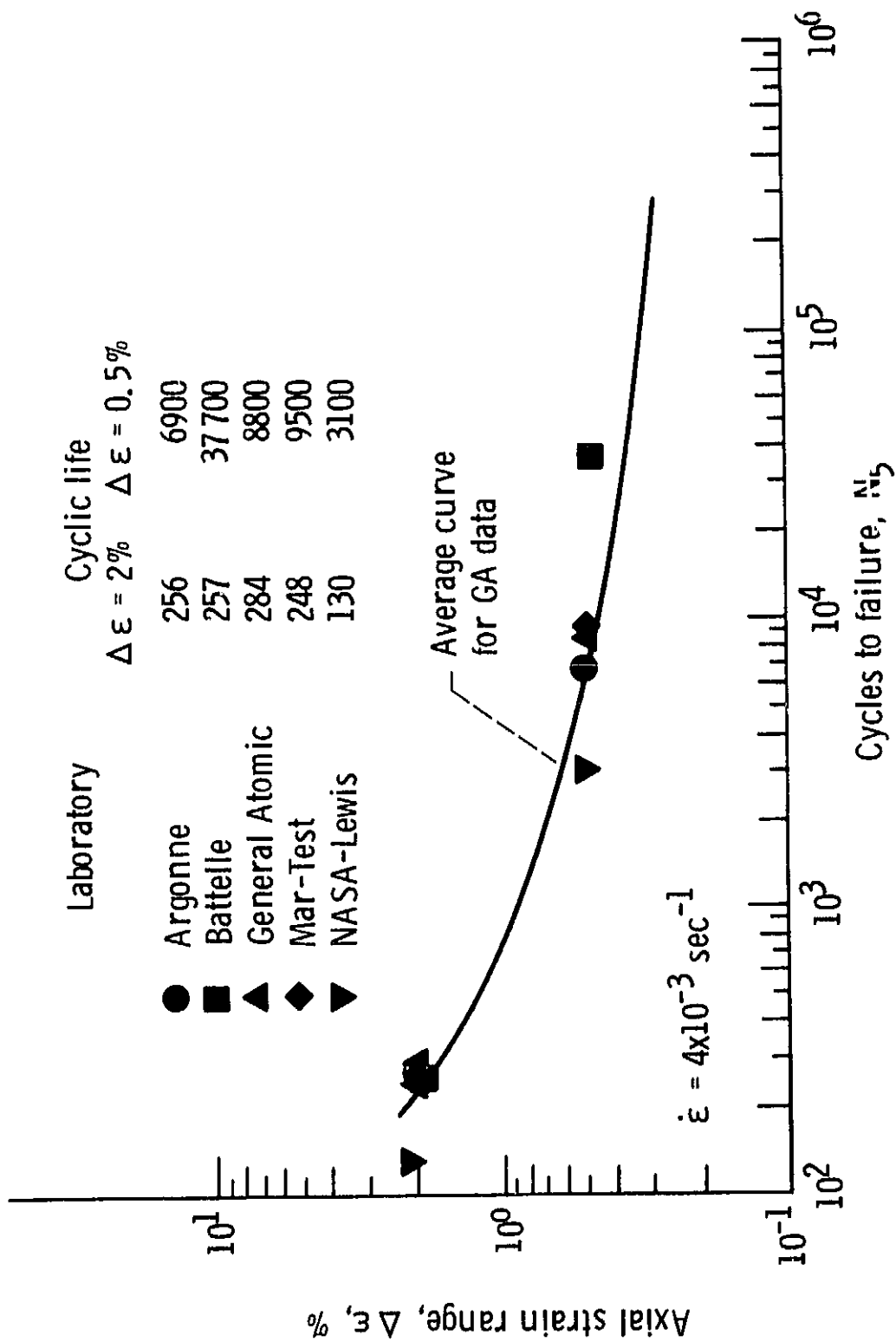


Figure 14. - Low-cycle fatigue data for Alloy 800H determined at 760 °C.

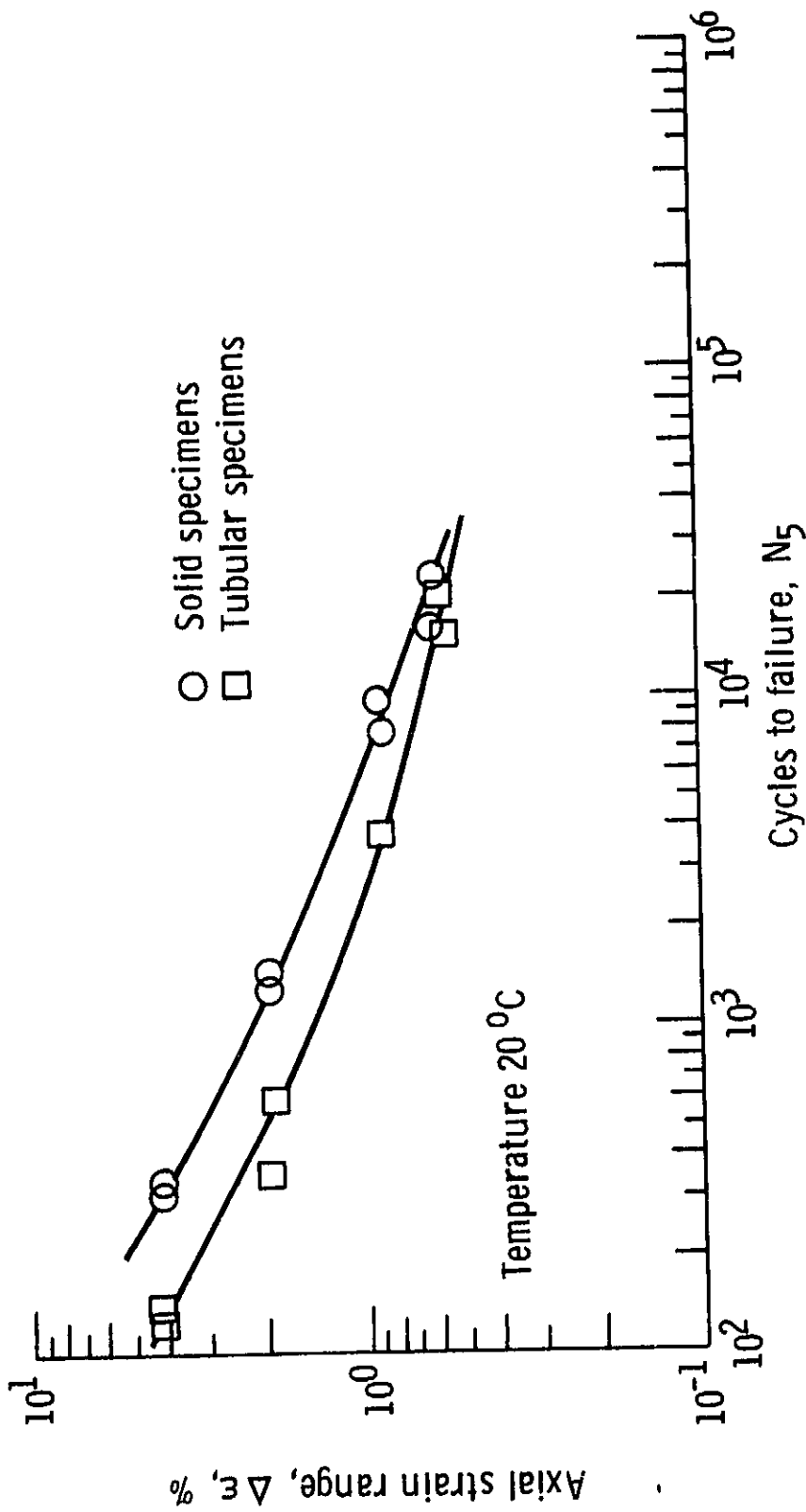


Figure 15. - Low-cycle fatigue data for high strength, low alloy steel determined at NASA-Lewis using solid and tubular specimens.

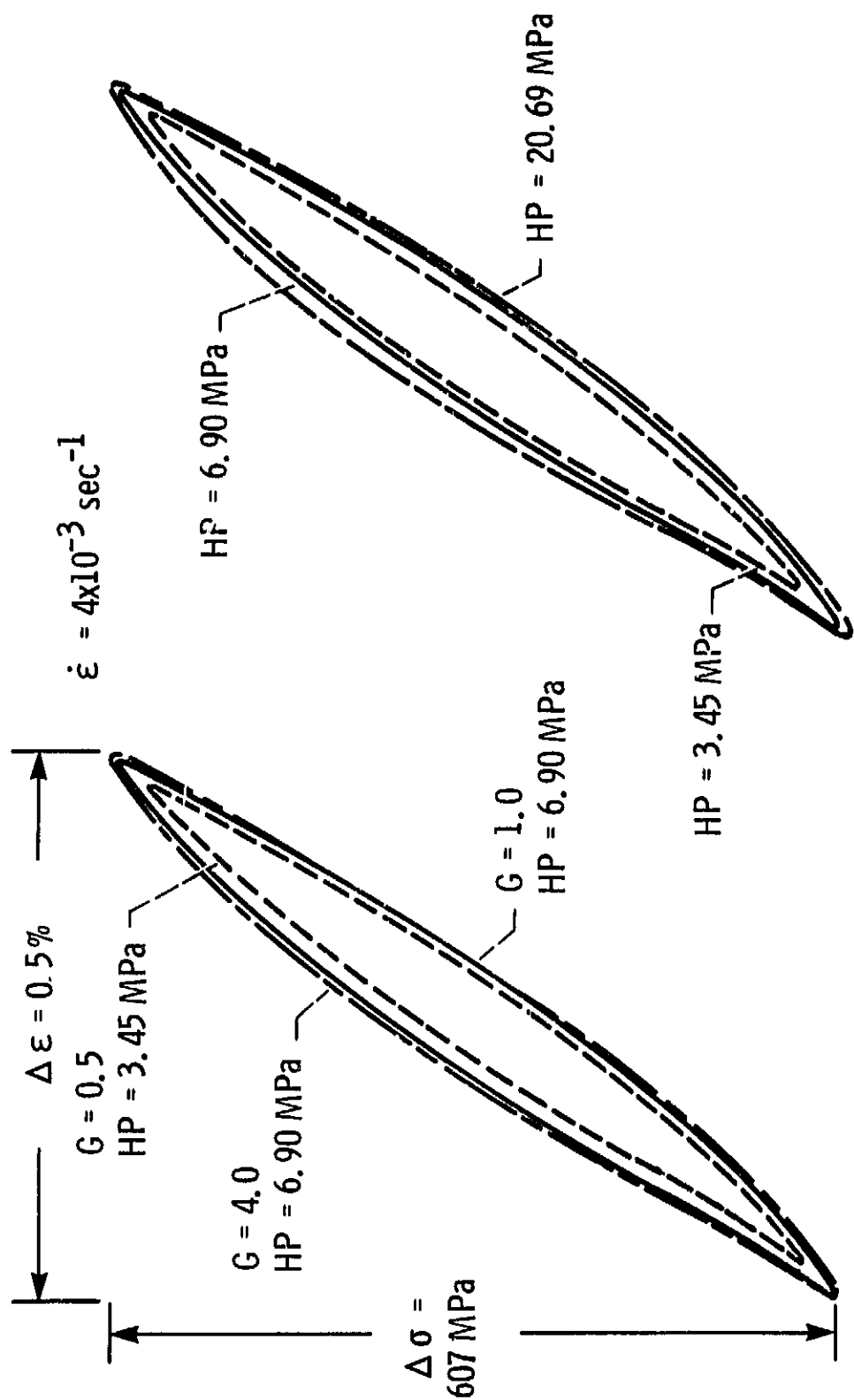


Figure 16. - Effect of varying test settings on the apparent stress-strain response of Alloy 800H at 20 °C.

Note: $\dot{\epsilon} = 2.6 \times 10^{-3} \text{ sec}^{-1}$ throughout

$\Delta \epsilon = 0.95\%$
 $\Delta \sigma = 733 \text{ MPa}$

$\Delta \epsilon = 0.97\%$
 $\Delta \sigma = 755 \text{ MPa}$

$\Delta \epsilon = 0.97\%$
 $\Delta \sigma = 760 \text{ MPa}$

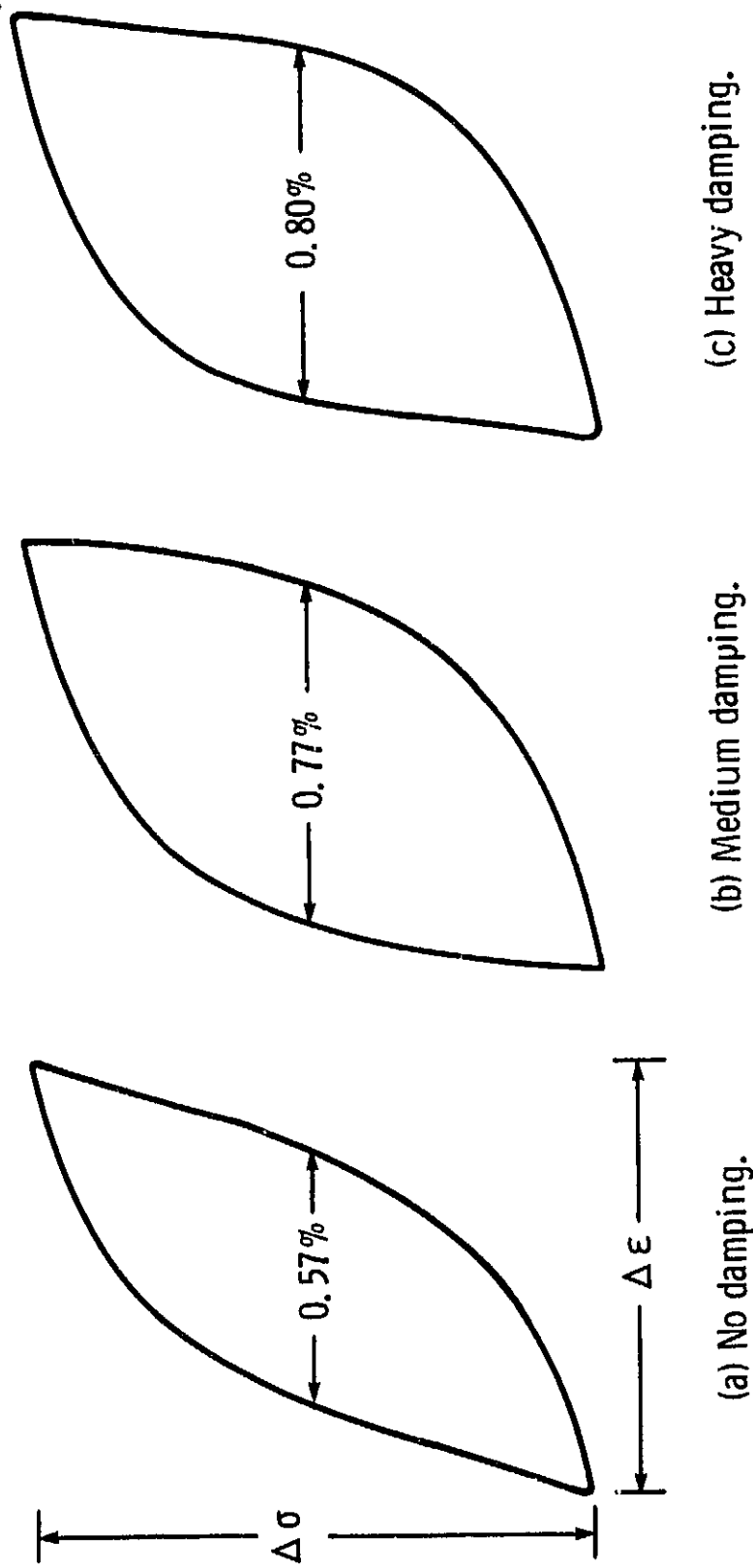


Figure 17. - Effect of extensometer damping on the apparent stress-strain response of Alloy 800H at 20 °C.

1. Report No. NASA CR-174940		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Results of an Interlaboratory Fatigue Test Program Conducted on Alloy 800H at Room and Elevated Temperatures				5. Report Date July 1985	
				6. Performing Organization Code	
7. Author(s) J.R. Ellis				8. Performing Organization Report No. None	
				10. Work Unit No.	
9. Performing Organization Name and Address The University of Akron Department of Civil Engineering Akron, Ohio				11. Contract or Grant No. NAG 3-379	
				13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546				14. Sponsoring Agency Code 533-04-12	
15. Supplementary Notes Final report. Project Manager, Daniel J. Gauntner, Structures Division, NASA Lewis Research Center, Cleveland, Ohio 44135. Work also sponsored by General Atomic Company, San Diego, California.					
16. Abstract A number of difficulties were encountered in early low-cycle fatigue tests conducted at General Atomic Company (GAC). The experimental approach adopted for this work involved the use of electro-hydraulic test systems, hour-glass geometry specimens, diametral extensometers, and axial strain computers. Attempts to identify possible problem areas with this approach were complicated by the lack of reliable data for the particular heat of Alloy 800H under investigation. The method adopted to resolve this difficulty was to generate definitive test data in an Interlaboratory Fatigue Test Program. The laboratories participating in the program were Argonne National Laboratory, Battelle Columbus, Mar-Test, and NASA Lewis. Fatigue tests were conducted on both solid and tubular specimens at temperatures of 20, 593, and 760 °C and strain ranges of 2.0, 1.0, and 0.5 percent. Based on the results of this study, it was concluded that the subject test method can, under certain circumstances, produce fatigue data which are seriously in error. As a result, this approach subsequently was abandoned at GAC in favor of parallel gage length specimens and axial extensometers.					
17. Key Words (Suggested by Author(s)) Instrumentation; Extensometers; High temperature; Low cycle fatigue; Alloy 800H				18. Distribution Statement Unclassified - unlimited STAR Category 39	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of pages 37	
				22. Price* A03	